ARTICLE

Climate Change and U.S. Interests

by Jody Freeman and Andrew Guzman

Jody Freeman is Archibald Cox Professor of Law, Harvard Law School. Andrew Guzman is Professor of Law, Berkeley School of Law.

I. Introduction

There is, after years of debate, a widespread though not universal consensus in the United States that climate change is real, that it is primarily the result of human activity, and that it poses a serious global threat.[1] A consensus on the appropriate U.S. response, however, remains elusive. While the new focus on climate change suggests that the United States may play a key role in attempts to negotiate a new international agreement to reduce global emissions,[2] there is serious debate in academic and policy circles over whether doing so would be in the national interest. Indeed, some argue that a straightforward cost-benefit analysis weighs against U.S. action.

The argument against American action goes something like this: Cutting greenhouse gas emissions will be costly for the United States, and it is not entirely clear that the benefits are worth it, especially since a warmer climate will impose fewer costs on the United States than on most countries.[3] Put another way, climate change is a collective action problem, and the best American policy would be to free ride on the efforts of more significantly affected states.[4]

This Article takes issue with this "climate change winner" argument. We demonstrate that its conclusions that harm to the United States will be small or perhaps even nonexistent reflect a significant misunderstanding of existing studies on the impact of climate change. If one examines those studies critically it becomes clear that the climate change winner argument is fatally flawed. The argument fails to account for the full spectrum of costs that climate change will impose on the United States, including spillover costs that the United States is almost certain to absorb. Once we account for both of these influences, the climate change winner argument withers, and the case for aggressive American action becomes compelling.

A. *The Climate Change Winner Argument and Its Limits*

The climate change winner argument relies on the consistent projections of both the scientific and economic literature that adverse effects of climate change will be distributed unequally.[5] The most affected countries will be those that have contributed the least to global greenhouse gas concentrations and are the poorest in the world.[6] That

This Article is excerpted from the Columbia Law Review, 109 Colum. L. Rev. 1531 (2009)*, and is reprinted with permission.*

Authors' note: The authors are grateful to Christopher Kutz, Dan Farber, Michael Gerrard, James Hines, Erin Murphy, Kal Raustiala, Kenneth Bamberger, Eric Posner, Richard Stewart, David Weisbach, and participants at faculty workshops at Berkeley Law School, NYU Law School, and the Latin American Law and Economics Association 2009 Annual Meeting for helpful suggestions during the preparation of the original draft of this Article; to Earth Duarte-Trattner, Karis Gong, Michael Kolber, Matt Littleton, and Elaine Meckenstock for outstanding research assistance; and to Lindsay See for superb editorial assistance on this condensed version. The original Article was written before the Obama Administration took office. The authors have added footnotes to acknowledge political developments that have occurred since then and their Reply addresses these developments more fully.

1. *See* Anthony Leiserowitz, *Climate Change Risk Perception and Policy Preferences: The Role of Affect, Imagery, and Values*, 77 Climatic Change 45, 46 (2006) ("Since the year 2000, numerous public opinion polls demonstrate that large majorities of Americans are aware of global warming (92%) ... and already view climate change as a somewhat to very serious problem (76%)."); *see also* Nat'l Acad. of Sci. et al., *Understanding and Responding to Climate Change 3* (2008), *available at* http://dels.nas.edu/dels/rpt_briefs/climate_change_2008_final.pdf (on file with the *Columbia Law Review*) (stating "[t]here is no doubt" climate change is occurring).
2. For a collection of proposals for what should replace the Kyoto Protocol, see Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World (Joseph E. Aldy & Robert N. Stavins eds., 2007).
3. For a characterization of this line of thought, see Cass R. Sunstein, *The World vs. the United States and China? The Complex Climate Change Incentives of the Leading Greenhouse Gas Emitters*, 55 UCLA L. Rev. 1675, 1677 (2008) [hereinafter *Complex Incentives*]. Though Sunstein advances the argument that the costs of action outweigh the benefits for the United States, he also argues that the United States may wish to act out of a sense of moral responsibility. *Id.* at 1696-98.
4. Several members of Congress employ this argument. *See e.g.*, 155 Cong. Rec. S202 (daily ed. Jan. 8, 2009) (statement of Sen. Inhofe); 154 Cong. Rec. S4022 (daily ed. May 12, 2008) (statement of Sen. Voinovich) ("Americans should not suffer for symbolism while countries such as China and India emit increasingly large quantities of greenhouse gases without consequences.").
5. *See* William Nordhaus & Joseph Boyer, Warming the World 96-97 (2000) (noting United States has "low vulnerability to catastrophic climate change"); Nicholas Stern et al., The Stern Review: The Economics of Climate Change 105 (2006) [hereinafter Stern Review] ("[Climate change] will have a disproportionately harmful effect on . . . poor communities who are already living at or close to the margins of survival.").
6. *See, e.g.*, Robert Mendelsohn et al., *The Distributional Impact of Climate Change on Rich and Poor Countries*, 11 Env't. & Dev. Econ. 159, 173 (2006) [hereinafter Mendelsohn et al*., Distributional Impact*].

the United States will fare better than most other countries has led some commentators to advance the climate change winner argument, claiming that it is irrational for the United States to take unilateral steps to mitigate climate change or to participate in a globally optimal international agreement to reduce emissions.[7]

The climate change winner argument relies on economic models of the impact of climate change on the United States. If one believes that the results of these models represent an accurate forecast of climate change impacts, then the climate change winner argument has considerable force. But these models provide only a lower bound on climate change's possible impact rather than an accurate prediction of its likely effects. They engage in a series of simplifying assumptions that, while necessary to make the models tractable, create a systematic downward bias on the projected impacts. The climate change winner argument fails to adequately consider this bias and so understates the threat of climate change.

No study to date has assessed all of the potential costs of climate change to the United States, including cross-sectoral, indirect, and cumulative effects on the U.S. economy[8] and nonmarket costs, such as loss of biodiversity and ecosystem services and the possibility of catastrophic losses.[9] These omissions are not anyone's fault, but rather result from the inherent limitations of economic modeling.[10] They also lead to a consistent bias toward an understatement of climate impacts. Ignoring these shortcomings has serious implications, however. Without a more complete cost-benefit analysis we cannot think coherently about the full range of likely impacts of climate change, and reliance on these models without a full understanding of their limitations could lead to misguided policy responses.

To date, the primary response to the climate change winner argument has been to insist that regardless of the cost-benefit calculation, the United States is morally obligated to act[11] either because it is the largest historic contributor to the problem (the corrective justice argument), or because it ought to help poorer nations (the distributive justice argument).[12] Alternatively, some suggest that the United States has an ethical obligation to future generations.[13]

In this Article, by contrast, we address, head-on, the cost-benefit calculus that lies at the heart of the climate change winner argument. Though we believe the moral arguments for U.S. action on climate change are compelling, we doubt that they will, on their own, convince U.S. policymakers of the need for mitigation. American international environmental policy is typically driven by utilitarian calculations about the national interest,[14] which in this instance has led to a remarkably powerful reluctance to act.[15] It persists even in the face of an increasingly solid scientific consensus that climate change is man-made, and pressure from state and regional climate programs,[16] the U.S. Supreme Court,[17] powerful industry players,[18] and the international community.[19] For this reason we restrict

7. Robert Mendelsohn & James E. Neumann, Synthesis and Conclusions, *in* The Impact of Climate Change on the United States Economy 315, 321 (Robert Mendelsohn & James E. Neumann eds., 1999) (noting warming may be beneficial to United States economy); Sunstein, *Complex Incentives*, *supra* note 3, at 1677 ("[American] unilateral reductions would impose significant costs and by themselves produce no significant benefits.").
8. Most models estimate direct market losses to agriculture, commercial water supplies, human health, and the like. *See generally* William Cline, Global Warming and Agriculture 67-71 (2007) (estimating impact of climate change on agriculture by country); Stern Review, *supra* note 5; Richard Tol, *Estimates of the Damage Costs of Climate Change Part II: Dynamic Estimates*, 21 Envtl. & Resource Econ. 135, 157 (2002).
9. *See generally* Robert L. Fischman, *The EPA'S NEPA Duties and Ecosystem Services*, 20 Stan. Envtl. L.J. 497, 498 (2001).
10. *See, e.g.*, R.O. Mendelsohn et al., *Country-Specific Market Impacts of Climate Change*, 45 Climatic Change 553, 567 (2000) (noting their models exclude nonmarket effects and have various other limitations) [hereinafter *Country-Specific*]; Mendelsohn & Neumann, *supra* note 7, at 317 (noting their model excludes nonmarket impacts, particularly health, aesthetic, and nonmarket ecosystem effects like species and wetlands loss).
11. *See, e.g.*, Daniel A. Farber, *The Case for Climate Compensation: Justice for Climate Change Victims in a Complex World*, 2008 Utah L. Rev. 377, 379.
12. *See, e.g.*, Daniel A. Farber, *Adapting to Climate Change: Who Should Pay?*, 23 J. Land Use & Envtl. L. 1, 18-34 (2007) (considering corrective and distributive justice in determining who should pay for climate change adaptations); Benito Müller, *Varieties of Distributive Justice in Climate Change*, 48 Climatic Change 273, 277 (2001) (considering distributive justice in emission allocations). *See generally* Edward A. Page, Climate Change, Justice, and Future Generations (2006) (examining climate change through lens of distributive justice).
13. *See* Page, *supra* note 12, at 7-11.
14. For example, the United States joined the Montreal Protocol, the treaty to eliminate ozone depleting substances, largely because the benefits of the agreement to the United States clearly outweighed the costs. *See, e.g.*, Cass R. Sunstein, *Of Montreal and Kyoto: A Tale of Two Protocols*, 31 Harv. Envtl. L. Rev. 1, 6 (2007).
15. Since this Article was first published, the United States did sign the "Copenhagen Accord" at the 15th Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change, in December 2009. While not an international treaty that includes targets and timetables for GHG mitigation, the Accord does commit all of the major economies, including China and other major developing countries, to an aspirational goal of limiting global temperature increase to 2 degrees Celsius; a process for countries to enter their specific domestic mitigation commitments by January 31, 2010; broad terms for the reporting and verification of countries' actions; a collective commitment by developed countries for $30 billion in "new and additional" resources in 2010-2012 to help developing countries reduce emissions, preserve forests, and adapt to climate change; and a goal of mobilizing $100 billion a year in public and private finance by 2020 to address developing county needs. *See* http://www.pewclimate.org/international/copenhagen-climate-summit-summary. The U.S. Congress has failed to pass legislation putting a market-based cap on carbon, and is currently implementing regulation of GHGs under the Clean Air Act. For a summary of regulatory initiatives under both the mobile and stationary source provisions of the Act, see http://www.epa.gov/climatechange/initiatives/index.html.
16. *See, e.g.*, California Global Warming Solutions Act of 2006, Cal. Health & Safety Code §§38500-38599 (West 2007) detailing California's state program to combat climate change); Reg'l Greenhouse Gas Initiative, Overview of RGGI CO_2 Budget Trading Program (2007), *available at* http://rggi.org/docs/program_summary_10_07.pdf (on file with the *Columbia Law Review*) (describing cap-and-trade coalition of Northeastern states).
17. Massachusetts v. EPA, 549 U.S. 497, 533-35, 37 ELR 20075 (2007).
18. Corporations that have joined the U.S. Climate Action Program, which advocates for strong federal regulation of greenhouse gases, include General Electric, Caterpillar, Shell, and the Environmental Defense Fund. U.S. Climate Action Partnership, *at* http://www.us-cap.org/ (last visited Aug. 21, 2009) (on file with the *Columbia Law Review*).
19. In January of 2009, for example, Stavros Dimas, the E.U. Commissioner for Environment, published an open letter calling on the United States to take a leadership role in efforts to reduce carbon emissions. Letter From Stavros Dimas, E.U. Commissioner for Environment, to President Barack Obama (Jan. 29, 2009), *at* http://ec.europa.eu/commission_barroso/dimas/news/doc/letterpresidentObama.pdf (on file with the *Columbia Law Review*).

our argument to consequences that would be taken seriously in a no-nonsense cost-benefit analysis. We argue that the calculation of American self-interest on which the climate change winner argument rests is simply mistaken. This is not because we dispute the general point that the United States may fare well relative to many other states in a warmer world, but because what matters are not the relative costs, but the absolute costs of inaction. If the absolute costs justify expenditures for mitigation, the U.S. government should make them.

B. Costs Omitted From the Climate Change Winner Argument

One of the more striking features of climate models, embraced (perhaps implicitly) in most climate change winner arguments, is a curiously isolationist approach to a truly global problem. They fail to consider, at least in any serious way, the possibility that many of that the harms that impact other countries are likely to spill over to the United States. We argue that this spillover is likely to occur in the form of national security threats, economic spillovers, spillovers resulting in the spread of infectious disease, human migration, and the risk of food and water shortages, species extinction, and biodiversity loss.

The United States cannot sequester itself from all such spillovers. To assume otherwise seems unduly optimistic—perhaps even naïve—given the reality of global interdependence. Economic, political, military, and public health developments in one region of the globe can have seismic impacts in another.[20]

Moreover, in our view, it is unlikely that the United States will react to world crises by attempting to retreat into isolation. If the United States hopes to shape its strategic position in an increasingly interdependent world, it must expect to bear at least some costs associated with responding to crises that arise elsewhere, including some that arise because of climate change. Yet a policy of U.S. isolationism is what the climate change winner argument implicitly assumes.

Even if a strategy of going it alone were possible, it would be extraordinarily expensive for the United States to try to insulate itself from outside events. Yet no model we know of accounts for the costs of isolationism.[21] Although such costs are hard to quantify, this challenge is no reason to count them as zero.

The fact that economic models fail to account for all relevant impacts is not news. The authors of these studies recognize as much and usually make their assumptions clear.[22] Our concern is not with the models themselves, but with the way in which some commentators and policymakers may interpret the results and overlook the limits that the assumptions impose. Climate change winner arguments tend to take the results of economic studies at face value, without serious consideration of their limits, and acknowledge imperfections in the economic models—if at all—only in footnotes and minor asides. Consequently, the fact that existing estimates systematically understate the likely impacts is ignored.

C. The Self-Interested Argument for Action

A more realistic assessment of relevant costs and benefit changes the calculus of whether it makes sense for the United States to cut domestic emissions. To the extent the argument against such action turns on prevailing estimates of the relative costs and benefits of doing nothing, we think it is wrong.

While it is surely correct that climate change poses a collective action problem, it is also true that large players may internalize enough of the benefits from the production of collective goods (here, mitigated climate change) to make it worthwhile to invest in those goods. A more complete accounting of cost matters because every player has an incentive to take action up to the point where the State's marginal cost of action exceeds the marginal benefit. A large, hegemonic player like the United States internalizes a significant fraction of the global gains of climate change abatement, making it worthwhile to bear at least some costs of emissions reductions.

Thus, a more comprehensive assessment of what the United States has at stake if climate change continues unabated suggests it is in the national interest to invest in mitigation. That is true even if the United States cannot fully internalize the benefits of mitigation, and even if some nations free ride on U.S. efforts.

It is important to separate the climate change winner argument we seek to debunk from other reasons why the United States might hesitate to act. For our purposes, these reasons are: (1) the "futility thesis"—the belief that any effort at mitigation will be overwhelmed by the sheer volume of emissions generated elsewhere; (2) the "leakage thesis"—the concern that any isolated effort at mitigation will be ineffective because emission-intensive industry will relocate to unregulated jurisdictions; and (3) the "fairness thesis"—which says it is simply unfair to expect the developed world to bear all the cost of mitigation.

These three concerns are quite different from the climate change winner argument. First, they do not dispute the basic proposition that climate change is a threat to the United States and that some form of global action is needed. Second, while they might be persuasive either alone or in combination, each requires a separate defense. For example, it is debatable whether unilateral cuts by the

20. C.B. Field et al., North America, *in* Intergovernmental Panel on Climate Change, Climate Change 2007: Impacts, Adaptation and Vulnerability 617, 640 (M.L. Parry et al. eds., 2007) [hereinafter IPCC, Impacts] ("In this interconnected world, it is possible that profoundly important impacts of climate change on North America will be indirect consequences of climate change impacts on other regions, especially where people, economies or ecosystems are unusually vulnerable.").

21. *See, e.g.*, Dale W. Jorgenson et al., *Pew Ctr. on Global Climate Change, U.S. Market Consequences of Global Climate Change*, at iii-iv (2004), *available at* http://www.pewclimate.org/docUploads/Market_Consequences-report.pdf (on file with the *Columbia Law Review*).

22. *See, e.g.*, *id.*

United States would, in fact, be futile. Futility predictions depend on controversial assumptions, including that U.S. leadership on emissions cuts will be met with international free riding, as if the United States has no instruments of persuasion at its disposal.

In any event, such arguments, though important, are not our focus here. We seek only to disprove the climate change winner argument, which we think takes too much for granted by bracketing the underlying methodological limitations of its cost-benefit analysis. In essence, we challenge the extent to which the United States ought to be viewed as a net "winner" from climate change by questioning what it means to be a "winner," especially in an interdependent world. How to count costs, what costs to include, and what to do when there is no established method for capturing costs are among the most important questions in the debate over U.S. action on climate change. A more comprehensive accounting reveals that it is in the United States' interest to take unilateral action to mitigate climate change, and, indeed, that the United States would be better off paying the full cost of mitigation (if this were possible) rather than allowing the world to continue in a "business as usual" fashion.

Our argument proceeds as follows: Part II explains why the methodologies of projections underlying the climate winner thesis are overly optimistic. Part III analyzes how spillover effects will impact the United States and generate additional, as yet unconsidered, costs. Part IV explains why the more complete assessment of costs justifies aggressive U.S. action to address climate change, notwithstanding some other countries' reluctance to act. We conclude by arguing that the risks of these costs justify unilateral action. If we are right, the case for American action strengthens considerably.

II. The Leading Scientific and Economic Projections

A. *Scientific Projections of Impact*

We take the predominant scientific consensus—that climate change is indeed occurring,[23] that its rapid acceleration in the last 150 years has been caused primarily by human behavior,[24] and that it poses significant risks of substantial harm from a variety of impacts—as a starting point. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (FAR) provides "best estimates" and "likely" ranges for global average temperature under six different scenarios with different assumptions about emission rates, technological development, and adaptation, among other things.[25] The IPCC's best estimate for the low emissions scenario is 1.8°C warming (with a "likely" range of 1.1°C to 2.9°C), and a best estimate for the high emissions scenario of 4.0°C warming (with a "likely" range of 2.4°C to 6.4°C).[26]

At current emission rates, GHGs are projected to reach an atmospheric concentration level of 550 ppm by 2050, which is expected to cause an increase in temperature of more than 2°C.[27] The more likely scenario, however, is that emissions will increase as economies grow,[28] especially developing economies, and that GHG concentrations will reach 550 ppm by 2035. The IPCC FAR projects that a variety of impacts—including loss of coastal lands, flooding that could displace hundreds of millions of people, more extreme weather events, stress on regional water supplies, and significant biodiversity loss—will occur under all the scenarios considered.[29]

These global estimates mask the fact that impacts will vary globally. There is little doubt that the United States is relatively well positioned to avoid the worst impacts. Not only is the United States geographically well situated to withstand the warming trend, but it has comparatively robust adaptive capacity from both strong domestic institutions and a relatively healthy, diversified economy.[30]

This story of relative effects, however, misses the point that, for policymaking purposes, it is absolute impact on the United States that matters. For this reason, the following section discusses the economic consequences of climate change in absolute terms and explains why existing economic projections systematically underestimate their impact.

23. Before industrialization, the average concentration of greenhouse gases in the atmosphere was approximately 280 parts per million (ppm). Hervé Le Treut et al., Historical Overview of Climate Change Science, *in* Intergovernmental Panel on Climate Change, Climate Change 2007: The Physical Science Basis 93, 100 (Susan Solomon et al. eds., 2007) [hereinafter IPCC, Physical Science Basis]. As of 2009 it was approximately 384 ppm. Earth Sys. Research Lab. Global Monitoring Div., Nat'l Oceanic & Atmospheric Admin., Trends in Atmospheric Carbon Dioxide, *at* http://www.esrl.noaa.gov/gmd/ccgg/trends (last visited Aug. 6, 2009) (on file with the *Columbia Law Review*). This change has caused the earth to warm by an average of 0.5°C, and will lead to at least an additional 0.5°C of warming in the coming decades. Stern Review, *supra* note 5, at 6, 15. Such increments of temperature rise may sound small, but small changes in global average temperature have significant impacts. *See* Mark Lynas, Six Degrees 17 (2008).

24. The most recent Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC FAR), which represents the consensus of the international scientific community, concludes that anthropogenic greenhouse gas emissions are "very likely" responsible for "most of the observed increase in global average temperatures since the mid-20th century." Richard B. Alley et al., Summary for Policymakers, *in* IPCC, Physical Science Basis, *supra* note 23, at 1, 10.

25. *Id.* at 18.

26. *Id.* at 11 tbl.SPM.3.

27. A recent analysis projects a temperature rise of 2°C in the long term even if there is no growth in emissions due to warming already "in the pipeline." James Hansen et al., *Target Atmospheric CO_2: Where Should Humanity Aim?*, 2 Open Atmospheric Sci. J. 217, 225 (2008).

28. Alley et al., *supra* note 24 at 12 ("For the next two decades, a warming of about 0.2°C per decade is projected.... Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.").

29. *Id.* at 12 ("Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES [Special Report on Emissions Scenarios] scenarios.").

30. The United States is not unique in this respect; other nations will also be less adversely affected. *See* Nordhaus & Boyer, *supra* note 5, at 96 (Japan, Russia, and China); Mendelsohn et al., *Distributional Impact*, *supra* note 6, at 170 (former Soviet Union and Eastern Europe); *see also* Stern Review, *supra* note 5, at 110-13 (discussing weak adaptive capacities of many developing nations).

B. *Economic Projections of Cost to the United States*

To generate estimates of the economic impact of climate change, economists rely on integrated assessment models (IAMs), which typically frame costs as changes in the level of gross domestic product (GDP) attributable to climate change.[31] Most of the economic models that focus specifically on the United States estimate that the long-term economic harm attributable to climate change will be between 0-3% of GDP.[32]

In this section, we explain why the methodological limitations of these models almost certainly cause them to understate the cost of climate change. We identify five problems that many of the studies share: optimism about projected temperature rise; failure to account for the possibility of catastrophic loss; omission of cross-sectoral impacts; exclusion of nonmarket costs; and optimism about projected economic growth.

1. Optimism About Temperature Rise. Creating an estimate of the economic impact of climate change begins with assumptions about the extent of warming over time. The most important economic studies to date have generally chosen relatively optimistic estimates about temperature changes, most in line with the IPCC FAR's low emissions scenario.[33] The resulting economic impact is 0-3% of global GDP lost.[34] If, however, one considers the possibility of 5-6°C warming, the economic impact is 5-10% of global GDP.[35]

Though it is possible that most IAMs overstate future warming,[36] it is much more likely that they underestimate the dangers we face. First, measurement difficulties cause some warming effects to be ignored.[37] Water vapor, for example, may increase the effects of rising carbon dioxide (CO_2) concentrations, but we do not know with any confidence how large such an effect could be.

Second, there is a possibility of "tipping points" or "threshold effects" which could result in "abrupt and irreversible change in the climate system"[38]—but are not factored into the IPCC FAR conclusions.[39] These include, for example, the risk of a rapid collapse of ice sheets in Greenland or the Antarctic.

Third, almost every surprise about climate change thus far has underestimated both the rate of warming and its effects. For example, Arctic sea ice is retreating at a significantly faster rate than predicted by the best computer models, including all eighteen models used by the IPCC in preparing the FAR.[40]

Fourth, the process that generated the projections makes understatement more likely than overstatement. There have been numerous allegations of political influence over the IPCC process, from charges that members have been voted out of the Panel for being overly aggressive in advocating policy responses[41] to claims that the IPCC has softened or deleted parts of the Report.[42] Governments with an interest in delaying progress on climate change have been known to challenge conclusions in assessment reports aggressively during the line-by-line approval process, leading to allegations that drafters ultimately weaken claims in order to garner consensus.[43] The process by which IPCC assessment reports are produced is highly constrained by the need for consensus, making it more likely to produce cautious and centrist conclusions.[44] It is also fair to suggest that as a matter of disciplinary training and shared norms, scientists tend to err in the direction of conservative estimates that can be defended on the basis of existing data.[45]

Many models also implicitly assume that GHG emissions will level off or decline very soon. Yet present estimates suggest just the opposite.[46] Annual GHG emissions

31. For examples of such models, see Nordhaus & Boyer, *supra* note 5, at 3-7 (Regional dynamic Integrated model of Climate and the Economy (RICE) and Dynamic Integrated model of Climate and the Economy (DICE)); Mendelsohn et al., *Country-Specific*, *supra* note 10, at 554 (Global Impacts Model).
32. *See* Joel B. Smith et al., Vulnerability to Climate Change and Reasons for Concern: A Synthesis, *in* Intergovernmental Panel on Climate Change, Climate Change 2001: Impacts, Adaptation and Vulnerability, at 913, 943 fig. 19-4 (summarizing several prominent IAM studies).
33. *See* Alley et al., *supra* note 24, at 13 tbl. SPM.3.
34. Stern Review, *supra* note 5, at 166 fig. 6.2.
35. Nordhaus & Boyer, *supra* note 5, at 95 fig. 4.3.
36. *See, e.g.*, David Henderson, *Governments and Climate Change Issues*, 8 World Econ. 183, 194-209 (arguing IPCC process has made numerous mistakes, especially in its treatment of economics, and is insufficiently transparent).
37. *See, e.g.*, Daniel P. Schrag, *Confronting the Climate-Energy Challenge*, 3 Elements 171, 173 (2007).
38. *Id.* at 174.
39. Alley et al., *supra* note 24, at 14.
40. *See* Julienne Stroeve et al., *Arctic Sea Ice Decline: Faster Than Forecast*, Geophysical Research Letters (May 2007) (arguing IPCC models underestimate real trends in ice melting).
41. *See* Al Gore, Op-Ed., *The Selling of an Energy Policy*, N.Y. Times, Apr. 21, 2002, §4, at 13.
42. Following the release of the Fourth Assessment Report in 2007, David Wasdell, who served as "an accredited reviewer of the report," viewed preliminary drafts of the report and asserted that "'reference to possible acceleration of climate change [was] consistently removed' from the final report." Fred Pearce, *Climate Report "Was Watered Down,"* New Scientist, Mar. 10, 2007, at 10.
43. David Biello, *Conservative Climate: Consensus Document May Underestimate the Climate Change Problem*, Sci. Am., Apr. 2007, at 16.
44. *See* Intergovernmental Panel on Climate Change, *Principles Governing IPCC Work*, app. A (2003), *available at* http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a.pdf (on file with the *Columbia Law Review*) (detailing procedures for production of IPCC reports and other materials)
45. To us, it is entirely reasonable to support a policy of taking somewhat more action than the IPCC projections indicate is necessary, both to account for the possibility that existing estimates understate the actual impacts and to recognize that some risk aversion is appropriate. To some commentators, climate change is a situation that calls for action as a kind of investment in insurance. *See, e.g.*, Richard A. Posner, Catastrophe: Risk and Response 56 (2004) ("It would thus be a mistake to say that because some climatologists doubt there is a global warming problem we can ignore the problem until climatologists get their act together and forge a unanimous agreement on the problem and its solution.").
46. Intergovernmental Panel on Climate Change, Synthesis Report 58 fig. 4.1 (2007), *available at* www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf (on file with the *Columbia Law Review*) (indicating under IPCC's A2 "business as usual" scenario, GHG emissions are expected to increase by thirty gigatons CO_2-e between 2000 and 2030). A recent study by Anderson and Bows shows that stabilizing CO_2-equivalent (CO_2-e) concentrations at 450 ppm (which yields a 46% chance of not exceeding 2°C warming) would

in the United States, for example, are projected to rise from 7.2 gigatons CO_2-e in 2005 to 9.7 gigatons in 2030,[47] and economic growth in the developing world is virtually certain to dramatically increase emissions.[48]

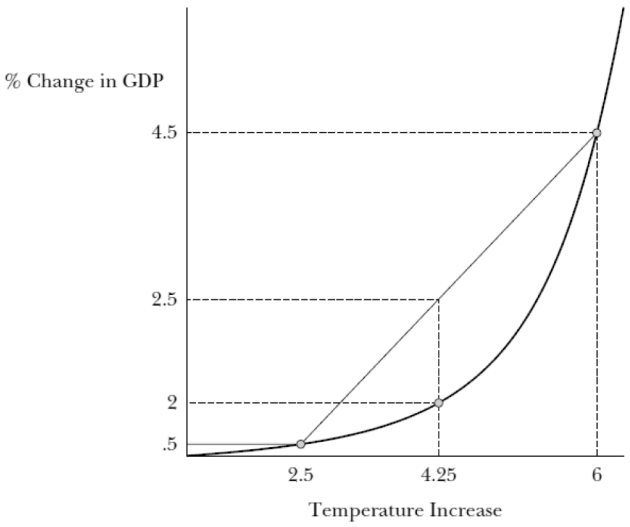
A focus on higher expected temperature change, along with associated changes in precipitation and other weather events, would significantly affect the predicted economic analysis. For example, assuming a temperature rise of 3-4°C instead of 2-3°C causes an additional estimated loss of approximately 1% of GDP.[49]

2. Asymmetry Around Point Estimates. An additional problem arises because discussions about climate change often focus on a single point estimate, rather than a range of temperature changes. The point estimate, while intuitively satisfying, produces misleading results because economic harm increases at an accelerating rate as temperatures rise.[50]

Increases in temperature around a given average will generally have a larger impact on economic well-being than will reductions in temperature. For example, a 2-3°C rise in temperature is expected to cause a 0-3% loss of GDP while a 5-6°C rise would reduce GDP by 5-10%.[51] Notice that doubling the assumed temperature increase from 3°C to 6°C more than triples the predicted economic impact. An accurate estimate of economic impacts, then, requires consideration of the full probability distribution of potential climatic changes.[52]

A better estimate would average the estimated economic impact over a range of possible climate outcomes. Figure 1 demonstrates this point, using data from Nordhaus and Boyer. They predict an impact on GDP of 0.5-4.5% where changes in global temperature range from 2.5-6°C.[53] The midpoint temperature increase would be 4.25°C, which Nordhaus and Boyer estimate would have an impact of 2% of GDP.[54] However, averaging the impact of a 2.5°C temperature increase (0.5% of GDP) and a 6°C increase (4.5% of GDP) yields an expected economic harm of 2.5% of GDP.[55] For policy purposes, the higher estimates more accurately reflect expected economic impact.

Figure 1: Temperature Increase Impact on GDP



Many (perhaps most) IAMs address this problem by estimating multiple scenarios, with alternative climatic assumptions.[56] When the results are deployed in policy discussions, however, the mid-range scenarios are the ones most frequently cited,[57] resulting in a tendency to understate climate change's expected economic impact.

3. Failure to Account for Catastrophic Events. Because IAM estimates are essentially extrapolations of existing experiences to expected climatic changes, they are unable to account for the risk of "catastrophic" climate events that could overwhelm all of the effects IAMs currently take into account.[58] While there is no doubt, for example, that

require heroic action to combat warming, with global emissions peaking in 2015, declining by 6-8% per year between 2020 and 2040, and eventually reducing to zero by 2050. Kevin Anderson & Alice Bows, *Reframing the Climate Change Challenge in Light of the Post-2000 Emission Trends*, 366 Phil. Transactions of the Royal Soc'y A 3863, 3877 (2008).

47. *See* McKinsey & Co., *Reducing Greenhouse Gas Emissions: How Much and at What Cost?*, at 6 (2007), *available at* http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf (on file with the *Columbia Law Review*).
48. Jayant Sathaye et al., Sustainable Development and Mitigation, *in* Intergovernmental Panel on Climate Change, Climate Change 2007: Mitigation of Climate Change 691, 706-07 (Bert Metz et al. eds., 2007).
49. Nordhaus and Boyer predict a 0.0-0.75% loss for the United States if temperatures rise 2-3°C, but a loss of 0.75-1.75% for a 3-4°C change in temperature. Nordhaus & Boyer, *supra* note 5, at 96 fig. 4.4. Note that because similar adjustments are appropriate to account for weaknesses in existing models, the cumulative impact is substantially greater.
50. The "average projected change in temperature" is typically cited as the midpoint of the 5-95% confidence interval of projected temperature changes. This confidence interval is generated using probabilistic techniques that incorporate various kinds of uncertainties. *See, e.g.*, Tom M.L. Wigley & Sarah C.B. Raper, *Interpretation of High Projections for Global-Mean Warming*, 293 Science 451, 451 (2001). In addition to asymmetry within the confidence interval, the exclusion of the most extreme 5% of temperature increases may lead to a downward bias in the point estimate.
51. Stern Review, *supra* note 5, at 166 fig. 6.2.
52. Using the average expected change in temperature also ignores the fact that the climate models do not account for the possibility of major shocks that might amplify the rise in temperature, such as unexpectedly rapid disintegration of major ice sheets.
53. Nordhaus & Boyer, *supra* note 5, at 96 fig. 4.4.
54. *Id.*
55. This simple averaging of the endpoints is fairly crude. Ideally one would calculate the expected change in GDP over the complete probability distribution function of potential temperature changes. This more thorough approach would yield similar results.
56. *See, e.g.,* Nordhaus & Boyer, *supra* note 5, at 96.
57. *See, e.g.*, Jerry Taylor & Peter Van Doren, *What Will Climate Change Cost Us?*, Dec. 18, 2008, Cato.org, http://www.cato.org/pub_display.php?pub_id=9850 (highlighting only mean, median, and modal summary estimates from IAMs). It should be noted, though, that in some secondary analyses, the use of point estimates is occasionally compelled by mathematical limitations. *See, e.g.*, U.S. EPA, *Analysis of the Lieberman-Warner Climate Security Act of 2008*, at 108 (2008), *available at* http://www.epa.gov/climatechange/downloads/s2191_EPA_Analysis.pdf.
58. Martin Weitzman, *On Modeling and Interpreting the Economics of Catastrophic Climate Change*, 91 Rev. Econ. & Stat. 1, 1-2 (2009). Weitzman argues that the low probability, highly uncertain scenarios of very large global average temperature increases (on the order of 10°C or more by 2200)

climate change will increase the incidence and the magnitude of floods, droughts, and storms, most IAMs do not adequately consider the potentially serious costs from such events.[59]

One exception is the study by Nordhaus and Boyer. By assuming a warming of 2.5°C they yield an estimated economic impact from catastrophic risk of slightly less than 0.5% of GDP for the United States, and about 1% globally. To this, one must add other impacts (agriculture, coastal resources, etc.), leading to a total estimate of harm of about 0.5% for the United States and 1.5% of GDP globally.[60] For a warming of 3-4°C, they predict loses of 1.5-2% of U.S. GDP. Using a relatively pessimistic assumption of 6°C warming yields an alarming forecast of a 10% loss of global GDP and 4.25% for the United States.[61]

4. Failure to Account for Nonmarket Costs. IAMs also tend to omit significant nonmarket costs, including those associated with the environment and human health.[62] These impacts are potentially enormous but the absence of reliable market prices makes them difficult to evaluate. A significant loss of biodiversity is very likely to occur yet is rarely included in estimates of economic harm, considered to be either too negligible or uncertain to quantify.[63] Although these costs are indeed difficult to quantify and hence uncertain, it is highly unlikely that they will be negligible.

Among the many reasons to be concerned about such significant biodiversity loss is a self-interested motive: the value of preserving biodiversity to support ecosystem services for human populations such as pollination, soil fertilization, and genetic resources used for medical research and pharmaceutical development.[64] These services would require considerable cost to replace—one study estimated their value in the mid-1990s at $33 trillion, about 1.8 times the value of global GNP at the time.[65] Although the portion of this value attributable solely to biodiversity is difficult to estimate as many ecosystem services are of mixed biological and nonbiological origin,[66] authors of another 1997 study estimated the value of biodiversity to be $319 billion annually for the United States and $2.93 trillion annually for the world.[67] Hsiung and Sunstein combined this estimate with the 15-37% estimated extinction rate to calculate the estimated value of biodiversity loss due to climate change in 2050 as $539-1,322 billion for the world and $58-144 billion for the United States.[68]

These are dramatic estimates, but they should nevertheless be viewed as conservative. To cite just one reason, the authors assume no more than modest temperature increases (0.8-2°C).[69]

The impact of species extinctions on human health and the pharmaceutical industry in particular illustrates the magnitude of these costs. Approximately 60% of anti-infective and anti-cancer drugs are either derived from or modeled after natural products.[70] The loss of the species from which such discoveries could be made is a cognizable economic loss. The magnitude of possible species losses at issue here—possibly one quarter to one half of species worldwide—overwhelms the argument that the value of any single species to new discoveries is negligible.[71] In addition to unexplored potential, some species that currently provide important services to human populations—like Rosy periwinkle, the source of two anti-cancer drugs[72]—may be threatened by climate change.

Therefore, although it is difficult to estimate the precise cost or harm to the ecosystem, strong evidence suggests that it is greater than zero, and potentially much larger. At a minimum, uncertainty cannot justify ignoring these costs altogether.

---

merit further investigation, because the potential economic impact of these high risk scenarios could overwhelm the conventional cost-benefit analysis of current IAMs. *Id.* at 1-2.

59. *See* Megan Ceronsky et al., *Checking the Price Tag on Catastrophe: The Social Cost of Carbon Under Non-Linear Climate Response* 18-21 (Hamburg Univ. & Ctr. for Marine & Atmospheric Sci., Working Paper FNU-87, 2005), *available at* http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/catastrophewp.pdf (on file with the *Columbia Law Review*).
60. Nordhaus & Boyer, *supra* note 5 at 91 tbl. 4.10. The impact on the United States is approximately 0.5% in both cases because the net impact in other sectors is roughly zero. The 1.5% global GDP loss is calculated by weighting countries by output level. Weighting countries by population yields a larger global GDP loss (about 1.9%). *Id.*
61. *Id.* at 95-96 figs. 4.3 & 4.4. Global GDP loss is calculated by weighting countries by output level. Weighting countries by population yields a larger loss of 11% of global GDP. *Id.* at 96 fig. 4.3. Intermediate temperature changes predictably yield intermediate results, with global GDP losses of about 5% for a 4°C warming and harm to the United States of slightly less than 2% of GDP for that same change in climate. *Id.* at 95-96 figs. 4.3 & 4.4.
62. *See* Richard S.J. Tol et al., *How Much Damage Will Climate Change Do? Recent Estimates*, 1 World Econ. 179 (2000), 191.
63. Although the impact on food production is often considered, the categories relating to natural biological processes have been ignored. Wayne Hsiung & Cass R. Sunstein, *Climate Change and Animals*, 155 U. Pa. L. Rev. 1695, 1716 (2007). *See also, e.g.*, Nordhaus & Boyer, *supra* note 5, at 85-87 (noting "rather wild" economic valuations of species extinction and serious need for quantitative work in area).
64. As the supply of ecosystem services approaches zero, the demand and total economic value approach infinity, because ecosystem services are necessary to support human life. *See* Robert Costanza et al., *The Value of the World's Ecosystem Services and Natural Capital*, 387 Nature 253, 257 (1997).
65. *Id.* at 259 (calculating figures in 1994 U.S. dollars).
66. *See* Wayne Hsiung & Cass R. Sunstein, Climate Change and Animals, 155 U. Pa. L. Rev. 1695, 1715-16 (2007) (noting significant portion of ecosystem value is generated by biological sources). Nonbiological services include, for example, ozone in the atmosphere for UVB protection and the weathering of rock in the soil formation process.
67. Daniel Pimentel et al., *Economic and Environmental Benefits of Biodiversity*, 47 BioScience 747, 748 tbl. 2 (1997).
68. Hsiung & Sunstein, *supra* note 66, at 1715-19. The low range in their estimates corresponds to a 0.8-1.7°C increase in global temperature, and the high range corresponds to an increase in global temperature that exceeds 2°C. *Id.* at 1703 n.37.
69. *Id.* at 1703 n.37. *See* Costanza et al., *supra* note 64, at 253 (noting their estimate represents minimum value because of uncertainties, which would probably increase "with the incorporation of more realistic representations of ecosystem dynamics and interdependence").
70. Walther H. Adey, *Coral Reef Ecosystems and Human Health: Biodiversity Counts!*, 6 Ecosystem Health 227, 232-33 (2000).
71. *See* Amy B. Craft & R. David Simpson, *The Value of Biodiversity in Pharmaceutical Research With Differentiated Products*, 18 Envtl. & Res. Econ. 1, 2 (2001).
72. Gordon C. Rausser & Arthur A. Small, *Valuing Research Leads: Bioprospecting and the Conservation of Genetic Resources*, 108 J. Pol. Econ. 173, 178 (2000).

5. Failure to Account for Cross-Sectoral Impacts. Many studies calculate costs on a sector-by-sector basis to arrive at an estimated aggregate impact.[73] This approach, though understandable given the complexity of considering all sectors simultaneously, understates the impact of climate change by not capturing potential cumulative impacts on a particular sector. To illustrate, we draw on the leading work of Robert Mendelsohn, who calculates the cost of climate change to the U.S. economy based on an enumerative approach that cannot account for either cross-sectoral or international spillovers.[74]

Mendelsohn begins with an estimate of climate change taken from one or more General Circulation Models, which attempt to predict what will occur as a result of warming.[75] He identifies several sectors (agriculture, forestry, coastal resources, energy, and water) likely to be sensitive to the estimated change in climate and projects a "climate-response function" to estimate the welfare impacts in each of these sectors.[76] The economic impact on a sector can be estimated as a function of temperature, precipitation, sea level rise, CO_2 concentration, and a set of additional parameters (e.g., land area, economic growth).[77] Mendelsohn then sums the sectoral impacts to produce an aggregate impact for a country.[78]

These models omit economic effects that implicate multiple sectors, however.[79] The impact of climate change on energy prices, for example, will not be reflected in the estimated impact of climate change on agriculture, even though climate-induced negative impacts on both water resources and the energy sector might combine to reduce agricultural outputs.[80] Mendelsohn attempts to measure the economic impact of climate change on agriculture, forestry, coastal resources, energy, and water independent of each other, and assuming all other economic forces are unaffected by that same climate change.

Cross-sectoral spillover effects might be insignificant if Mendelsohn's assumption of 2°C warming proves accurate, and if the impact of climate change in each sector turns out to be both positive and very small, as he has found.[81] If, however, warming turns out to be greater than 2°C, some of the impacts in the United States become more worrisome, and there is a greater risk of costly interaction among the sectors.

6. Growth, Productivity, and Long-Term Projections. Finally, existing IAMs tend to be static, representing a snapshot of the economic situation. They generate predictions by varying one variable at a time, which greatly simplifies the task, but fails to capture other changes in the system. That failure is particularly problematic when, as with predicting climate change impacts, the analysis covers very long time periods of, say, 100 years or more, over which time the rate of economic growth will have a critical influence on economic welfare. A 2% growth rate over 100 years implies a more than seven-fold increase in the size of the economy, but a 1% growth rate would lead to an economy less than half that size. It follows that when estimating the value of mitigation, investments today to prevent even a small reduction in growth rates can yield enormous future benefits. A reduction in GDP due to climate change is likely to cause a drop in investment. Lower investment will, over the long term, cause a reduction in the capital stock and, therefore, a drop in productivity.

Fankhauser and Tol estimate the impact of such a reduction in saving and investment[82] and find that the capital accumulation effects are more important in places where climate change impacts are modest overall.[83] Under certain conditions they find that the capital accumulation effect may be larger than the "direct impact" measured by existing models. In other words, accounting for the capital accumulation effect may cause estimates of harm to be doubled.

III. Spillovers

Overlooking international spillovers also leads existing models to understate the likely costs of climate change. Virtually all models to date have focused on a single part of the world; there is almost no discussion of how impacts in different countries, and across regions, might affect other parts of the world.

Observers calculating climate change costs generally examine only the direct—and geographically local—costs of a change in the environment.[84] Yet it hardly needs emphasizing that in this era of globalization the economic security of the United States relies heavily on political and economic stability in other parts of the world. We can only understand the impact of climate change on the United States if we understand how its impact elsewhere affects us. To illustrate, the Nordhaus and Boyer model predicts that a 6°C warming would reduce European GDP by about

73. *See, e.g.*, Nordhaus & Boyer, *supra* note 5, at 10-12; Robert Mendelsohn & Michael E. Schlesinger, *Climate-Response Functions*, 28 AMBIO 362, 363 (1999); Robert Mendelsohn & Larry Williams, *Comparing Forecasts of the Global Impacts of Climate Change,* 9 Mitigation & Adaptation Strategies for Global Change 315, 323 (2004).
74. *See, e.g.,* Mendelsohn et al., *Country-Specific*, *supra* note 10, at 554-60.
75. For example, in his 2006 article, Mendelsohn uses two different University of Illinois at Champaign-Urbana (UIUC) models: the UIUC11 and UIUC2 models. Mendelsohn et al., *Country-Specific*, *supra* note 10, at 555. Mendelsohn & Williams, *supra* note 73, at 316, use five models.
76. Mendelsohn et al., *Distributional Impact*, *supra* note 6 , at 161.
77. *Id.* at 161, 163.
78. *Id.* at 161.
79. The climate-response functions do take into account that the economy will grow over time, but they ignore the possibility that harm in one sector may have an impact on other sectors or that harm abroad could affect the United States.
80. Mendelsohn et al., *Country-Specific*, *supra* note 10, at 558 tbl. 1.
81. *Id.* at 558.
82. Samuel Fankhauser & Richard S.J. Tol, *On Climate Change and Economic Growth,* 27 Resource & Energy Econ. 1, 3-6 (2005).
83. *Id.* at 13.
84. Although we are concerned in this Article with U.S. policy, many of the indirect effects we describe will affect other countries as well. That includes some countries that are crucial to solving the climate change problem, such as India and China.

17%.[85] Were Europe to face harms of this magnitude, there is little doubt that there would be serious consequences for the United States.[86]

Economic models of climate change do not take such spillovers into account for good reason: It is difficult enough to estimate the impacts within a single economy. Additionally, the methodological limitations in even our most advanced models leave us with only a partial picture of the likely impacts and costs of climate change. It would thus be unfair to criticize IAMs as being poorly or irresponsibly done. That said it is critical for policymakers to keep the models' limitations in mind, including their failure to account for cross-border spillovers. As we show below, once one takes into account the likely spillovers from climate change, the costs to the United States are clearly much larger than typically portrayed.

The analysis below focuses on a number of areas in which the United States is likely to suffer negative consequences from climate change. The magnitude of these spillovers will obviously depend on the impact of climate change on other countries. To give some perspective, recall that the Stern Review estimates that a "business as usual" approach would lead to a global reduction in per capita consumption of 20%.[87] Even if this estimate overstates the actual impact, many parts of the world stand to be badly affected, creating competition for resources, demands for political change, increased migration, more disease, and other harms that would negatively impact American interests and require U.S. investment of resources.

A. *Economic Spillovers*

Although the costs of reducing GHGs will be significant, the cost of not reducing them may well be even greater. There is widespread, if not universal, agreement that climate change will have a large impact on many parts of the world, including relatively wealthy Europe, where rising seas are projected to bring severe flooding, land loss, salinization of groundwater, and the destruction of physical infrastructure.[88] Other parts of the world stand to suffer even more. In Asia, decreases in crop yields are expected to place hundreds of millions of people at risk of hunger, while large-scale hydrologic changes will expose millions more to epidemics.[89] In Africa, the food and water security consequences of climate change are projected to be particularly grave, especially given the continent's already limited capacity to adapt.[90] In Latin America, water stress and extreme loss of biodiversity are expected in fragile ecosystems.[91]

The United States is integrated into the world economy in many important ways. With respect to trade, for example, eleven percent of American GDP is exported, and seventeen percent is imported.[92] Private parties in the United States benefit from opportunities to invest and do business abroad, and rely on the global financial community to raise capital. In these and countless other ways, the United States benefits from engagement with the rest of the world.

It is admittedly impossible to assign dollar amounts to American losses resulting from climate change in other parts of the world. The precise amount of warming experienced by foreign countries and the associated environmental impacts are uncertain, and the effect of these changes on the economies, governance, and behavior of foreign countries is difficult to predict. How much stress on the availability of freshwater in the Persian Gulf region will it take to cause a major disruption in the oil supply? Will Europe adopt protectionist strategies in reaction to the pressures generated by climate change? It is also difficult to anticipate how the supply and demand of many American imports will be affected. Even if all of the relevant impacts were known, the predictions of the appropriate economic models come with large variances.

The inability to generate precise numerical estimates of the economic impact of climate change spillovers does not mean, however, that they are unlikely to occur. The discussion that follows confirms the intuition that American integration into the international economic system virtually guarantees that broad-based and substantial hardship abroad will lead to welfare losses in the United States. Any sensible policy consideration of the costs of climate change on the United States must account for the prospect of such impacts.

1. Shocks to International Trade. The first and most obvious way that climate change's foreign impacts are likely to affect American trading interests is through diminished trade flows. To the extent the foreign markets for American products contract, American exporters will suffer. To the extent that foreign sources of production are affected by climate change, American imports may become more expensive or of lower quality. If states (including the United States) engage in protectionism as a response to climate change, the effects on both imports and exports will be further aggravated.

85. Nordhaus & Boyer, *supra* note 5, at 96 fig. 4.4.
86. There are other synergistic and multiplier effects that might arise if one considers the possibility of both cross-sectoral and international spillovers. *See supra* Part II.B.5.
87. Stern Review, *supra* note 5, at 186-87.
88. Joseph Alcamo et al., Europe, *in* IPCC, Impacts, *supra* note 20, at 541, 551.
89. *See* Rex Victor Cruz et al., Asia, *in* IPCC, Impacts, *supra* note 20, at 469, 471 (summarizing effects of climate change on Asia).
90. Michel Boko et al., Africa, *in* IPCC, Impacts, *supra* note 20, at 433, 435.
91. Graciela Magrin et al., Latin America, *in* IPCC, Impacts, *supra* note 20, at 581, 583.
92. U.S. Census Bureau, Foreign Trade Div., U.S. Trade in Goods and Services—-Balance of Payments Basis (June 10, 2009), *at* http://www.census.gov/foreign-trade/statistics/historical/gands.txt (on file with the *Columbia Law Review*) [hereinafter Census—-U.S. Trade (BOP Basis)]; World Bank, World Development Indicators, *at* http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20398986~menuPK:64133163~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html (last visited Aug. 7, 2009) (on file with the *Columbia Law Review*) [hereinafter World Bank Indicators].

A conventional approach to short-run supply shocks assumes that their impact fades over the long term. In the context of climate change, however, there are good reasons to think these shocks may last beyond the short term. First, because climate change is a process playing out over many years with potentially profound impacts, it is at least plausible that the world will face a series of serious to severe supply shocks stretching over an extended period of time. These events could severely hamper economies for decades, creating a lasting economic (not to mention political and social) crisis.

A second way in which supply shocks could have long-term effects is through a loss of raw materials. Climate change poses a serious threat to the supply of critical resources like water and energy, and severe shortages of either could wreak havoc on worldwide production for decades. In standard economic models the long-run rate of growth is ultimately determined by productivity, which is taken to be exogenous. If growth is to be affected in the long run, then it must be through productivity.[93] Unfortunately, there are no good models of factors that influence productivity, making it difficult to assess the impact of a hypothetical shock on long-term growth rates.

We live in a global market with global prices. If climate change has the effect of driving up prices due to a supply shock, then the United States will suffer along with everyone else. Such a shock could result from water shortages in Asia (as Himalayan glaciers melt), a disruption in energy supply from the Middle East and Africa, a drop in global food production due to changing climatic conditions, or any of the many other possible disruptions that could take place. Any of these outcomes would harm the United States along with everyone else in the world.

In addition to the above supply shocks, demand for American exports may be reduced by the economic harm imposed by climate change on foreign states. As discussed in the context of supply shocks, these demand shocks would normally be considered short-term rather than long-term problems. To the extent climate change creates a series of negative demand shocks spread over many years, however, the impact on the United States could be felt for generations. Table 1 shows the contribution of exports to the U.S. economy in recent years.

Table 1: U.S. Exports as Percentage of GDP[94]

Year	Exports (% of GDP)	Exports (Billions of $)
1993	9.9	654
1994	10.3	723
1995	11.1	812
1996	11.2	869
1997	11.6	934
1998	11.0	933
1999	10.8	966
2000	11.2	1071
2001	10.3	1005
2002	9.7	975
2003	9.5	1018
2004	10.1	1161
2005	10.5	1284
2006	11.1	1457
2007	11.6	1646
2008	12.9	1843

To get some sense of the impact that a reduction in trade might have, we turn to the economic literature on the gains from international trade.[95] Note that total estimated gains to the United States from trade are enormous, on the order of $1 trillion per year since the Second World War.[96] This represents a permanent increase in national income, meaning the gain is enjoyed every year.[97] How much of that value is at risk from climate change depends on how much trade is disrupted. One way to get a sense of the potential magnitudes is to examine the impact of recent events, such as the economic impact to the United States of the trade liberalization associated with the WTO's Uruguay Round, which took effect in 1995. Brown, Deardorff, and Stern estimate that the total impact of the agreement that emerged from this round of trade talks was $19.8 billion,[98] which represents slightly more than one quarter of 1% of U.S. GDP in 1995.[99] The trade flows that generated this modest increase in GDP were a similarly modest increase in imports of about $19 billion and an increase in exports of about $18 billion.[100] Assuming that climate change causes a significant contraction of foreign demand for U.S.

93. The previous two examples of how climate change might have a long-run impact are consistent with this statement. The first, that the shocks may themselves persist over decades, is really a claim that the "long term" is sufficiently far off that we should be concerned with short-term shocks. The period over which the shocks continue is most accurately called the short term, but when this period extends to fifty years or more, the importance of worrying about the short term is clear. The second example is a special case of a shock affecting productivity. If natural resources (or any other essential inputs) are scarce, the productivity of labor is reduced and prices (though not wages) rise.

94. World Bank Indicators, *supra* note 92. The query was limited to Country: United States, Series: Exports of goods and services (% of GDP), and Time: 1993 through 2008. For 2006–2008 census data, see Census—U.S. Trade (BOP Basis), *supra* note 92.

95. *See generally* Scott C. Bradford et al., The Payoff to America From Global Integration, in the United States and the World Economy: Foreign Economic Policy for the Next Decade 65-66 (C. Fred Bergsten ed., 2005) (summarizing gains in post-World War II trade and gains to come); Drusilla K. Brown et al., *Computational Analysis of Multilateral Trade Liberalization in the Uruguay Round, in The World Trade Organization: Legal, Economic and Political Analysis*, Part III: Economic, Political and Regional Issues 23 (Patrick F.J. Macrory et al. eds., 2005) [hereinafter Brown et al., *Computational Analysis*] (describing international trade as driving increased national income).

96. Bradford et al., *supra* note 95, at 68.

97. *Id.*

98. Brown et al., *Computational Analysis, supra* note 95, at 31.

99. World Bank Indicators, *supra* note 92 (citing for GDP amount).

100. Brown et al., *Computational Analysis*, *supra* note 95, at 28 tbl. 1.

goods, one would expect much larger effects. To illustrate, see Table 2 for the impact of the recession of 2009-2010 on exports.

Table 2: U.S. Monthly Exports[101]

Period	Exports (Billions of $)
January 2008	149
February 2008	153
March 2008	150
April 2008	155
May 2008	157
June 2008	163
July 2008	167
August 2008	165
September 2008	154
October 2008	150
November 2008	141
December 2008	133
January 2009	125
February 2009	127
March 2009	124

As the chart shows, US exports fell 25% from their peak in July 2008 to March 2009. This is a much larger shock than that considered by Brown, Deardorff, and Stern. If one assumes that climate change will cause a disruption in trade flows half as large as what was experienced from July 2008 to March 2009, the result is a reduction in exports of about $20 billion per month, or $240 billion per year. As Table 1 shows, this would not be out of line with fluctuations in exports that we have seen over the last fifteen years.

What would be the impact of this reduction in trade flows on welfare? The Brown, Deardorff, and Stern estimates suggest a rough 1:1 ratio between exports and GDP impact, at least over this relatively modest increase in exports. Bradford, Grieco, and Hufbauer estimate the total impact of trade and investment to be approximately $1 trillion in 2003.[102] In 2003 the United States had just over $1 trillion in exports.[103] Again, we see a 1:1 ratio between exports and welfare impacts. Assuming that this ratio is accurate, the above-mentioned $240 billion reduction in exports can be expected to correspond to a $240 billion reduction in welfare—more than 1.5% of 2008 GDP.

2. Financial Markets. Climate change's impact on financial markets may be even more important than its trade effects. The United States has run a current account deficit for many years, with the difference between imports and exports being made up with borrowing from abroad.[104] As countries suffer climate-induced economic contraction, perhaps for long periods of time, their enthusiasm for continuing to lend to Americans is likely to wane more quickly than it otherwise would. In practical terms, this reluctance to lend would mean higher interest rates in the United States, a contraction of investment, and a reduction in consumption.

Of course financial markets matter for more than simply bringing the current account into balance. Private parties in the United States, including virtually all of the largest and best known American firms, invest abroad and could face losses if foreign economies suffer. This translates to lower returns on investment in these firms for everyone, including individual shareholders.

More systemically, there is a risk that a global economic downturn would lead to a drying up of capital markets, an increase in the cost of credit, and a resulting reduction in investment. Climate change could trigger such global slowdowns in the future, and it is clear that the United States would be unable to isolate itself from the impacts.

B. National Security

Until recently, climate change received virtually no sustained analysis in either academic or policy circles as a potential threat to national security.[105] In the last few years, however, a number of important studies on the topic have emerged from well-respected academic, government, and nongovernment sources. In 2008, the National Intelligence Council produced the most comprehensive analysis to date of the implications of climate change for U.S. national security over the next twenty years.[106] According to news reports, the classified assessment concluded that climate change could destabilize fragile political regimes, exacerbate conflicts over scarce resources, increase the threat of terrorism, disrupt trade, and produce millions of refugees—all of which would seriously affect U.S. national security interests.[107]

The consistent message of these studies is that while climate change may not provoke national security threats by itself, it is certain to be a "threat multiplier,"[108] exac-

101. Press Release, Foreign Trade Div., U.S. Census Bureau, U.S. International Trade in Goods and Services, *available at* http://www.census.gov/foreign-trade/Press-Release/current_press_release/exh1.pdf (last visited Aug. 22, 2009) (on file with the *Columbia Law Review*).
102. *See* Bradford et al., *supra* note 95, at 69.
103. *See* Census—U.S. Trade (BOP Basis), *supra* note 92.
104. *See* Press Release, Bureau of Econ. Analysis, U.S. Dep't of Commerce, U.S. International Transactions: First Quarter 2009 (June 17, 2009), *available at* http://www.bea.gov/newsreleases/international/transactions/2009/pdf/trans109.pdf (on file with the *Columbia Law Review*).
105. Jon Barnett, *Security and Climate Change 2* (Tyndall Ctr. for Climate Change Research, Working Paper No. 7, 2001) (on file with the *Columbia Law Review*).
106. *See* Tom Gjelten, *Intel Report Eyes Climate Change-Security Link*, NPR, June 23, 2008, *at* http://www.npr.org/templates/story/story.php?storyId=91819098 (on file with the *Columbia Law Review*) (describing classified report).
107. *Id.*
108. *See National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030: Joint Hearing Before the H. Select Comm. on Energy Independence and Global Warming and the H. Permanent Select Comm. on Intelligence*, 110th Cong. 4-5 (2008) (statement of Thomas Fingar, NIC Chair) [hereinafter *Fingar Statement*], *available at* http://globalwarming.house.gov/tools/2q08materials/files/0069.pdf (on file with the *Columbia Law Review*) ("[T]he most significant impact for the United States will be

erbating political instability around the world as weak or poor governments struggle to cope with its impacts.[109] In especially hard hit nations, deteriorating economic conditions could lead to the fall of governments, creating, at worst, safe havens and, at best, fertile recruiting grounds for terrorist groups. Floods, droughts, and conflicts over scarce resources are projected to create refugees—"climate migrants"—potentially inflaming political tensions and burdening the already-stressed economies in host nations.[110] Climate change also threatens to interrupt the free flow of trade in critical resources such as oil, gas, and other essential commodities on which the United States depends.

Though the message from the national security studies is unambiguous, none of the leading studies of economic impacts have tried to quantify these effects. It is possible, however, to provide a qualitative sense of potential threats that ought to be factored into any analysis of climate policy.[111] We offer some examples below.

In Asia, rising global temperatures are projected to result in reduced agricultural productivity, shrinking supplies of drinkable water, and increased risk of flood, drought, and extreme weather events.[112] Many glaciers in Asia could, at current rates of climate change, disappear within the coming decades.[113] Such a disappearance would have serious long-term consequences for the half billion people in the Himalaya-Hindu-Kush region, and for an additional quarter billion people downstream, in countries like Pakistan, who rely on glacial melt waters for their water supply.[114] In addition, cereal crop yields are expected to drop between 2.5 and 10% in South, Southeast, and East Asia, contributing to a risk of hunger for as many as fifty million people as soon as 2020.[115]

These impacts will have spillover effects on the United States. For example, Bangladesh could find the fifth of its country comprised of low-lying regions uninhabitable by the end of the century.[116] Bangladesh has already become a security concern for the United States as the impact of Islamic extremism has grown.[117] The effects of population displacement from flooding,[118] along with additional economic stress in an already unstable region, are likely to create fertile grounds for terrorist groups.[119]

China, a rising international power of tremendous strategic importance to the United States, is also vulnerable to disasters precipitated by climate change.[120] Climate change likely will affect China by reducing water supplies in the North, causing extreme weather in the South, and raising the sea level, threatening hundreds of millions of people in densely populated coastal regions.[121] China faces serious indirect costs, as well, as it is especially vulnerable to unstable energy supplies in regions that will be among the hardest hit by climate change.[122] A serious interruption of supply could considerably slow China's growth, which could in turn undermine the legitimacy of the ruling Communist Party, leading to political instability. While this series of events is speculative, it is certainly plausible.

The impact of climate change on many nations in Africa is projected to be especially severe, with their high risk of impact and low adaptive capacity.[123] Moreover, Africa possesses critical natural resources over which there is increasingly intense competition,[124] and various countries in Africa pose a risk to the United States as potential bases for terrorist groups. Consider the impact of climate change on Nigeria, on which the United States increasingly depends for oil.[125] Nigeria already faces severe challenges as rebel groups undertake attacks in an effort to disrupt oil production,[126] and would risk further major domestic turmoil as a result of climate change. It is easy to imagine a collapse in oil exports due to a combination of increased rebel activity (fueled in part by more acute struggles for food and water throughout Nigeria and the continent) and

indirect and result from climate-driven effects on many other countries and their potential to seriously affect US national security interests."); Ctr. for Strategic & Int'l Studies & Ctr. for a New Am. Security, The Age of Consequences: The Foreign Policy and National Security Implications of Global Climate Change 103, 105 (Kurt M. Campbell et al. eds., 2007), *available at* http://www.cnas.org/files/documents/publications/CSIS-CNAS_AgeofConsequences_November07.pdf (on file with the *Columbia Law Review*) (describing different impacts of climate change on world and arguing it "has the potential to be one of the greatest national security challenges that this or any other generation of policymakers is likely to confront") [hereinafter *Age of Consequences*.].

109. *See* John M. Broder, *Climate Change Seen as Threat to U.S. Security*, N.Y. Times, Aug. 9, 2009, at A1.

110. *See infra* Part III.C.

111. Consistent with the leading assessments, we adopt a broad definition of "national security." *See Fingar Statement*, *supra* note 108, at 3 (describing NIA definition: "We first considered if the effects would directly impact the US homeland, a US economic partner, or a US ally. We also focused on the potential for humanitarian disaster [and] ... if the result would degrade or enhance... Geopolitical, Military, Economic, or Social Cohesion....").

112. Victor Cruz et al., *supra* note 89, at 471.

113. Nearly 70% of the world's freshwater is locked in glaciers and icebergs, which are already melting because of climate change. Adger et al., Summary for Policymakers, *in* Climate Change 2007: Impacts, Adaptation and Vulnerability 13 (M.L. Perry et al. eds, 2007).

114. Current trends in glacial melt suggest that the Ganga, Indus, Brahmaputra, and other rivers in India may become seasonal rivers as a consequence of climate change, which could significantly and adversely affect the economies in the region. Victor Cruz et al., *supra* note 89, at 493.

115. *See Fingar Statement*, *supra* note 108, at 8-9.

116. Stern Review, *supra* note 5, at 104, 129.

117. Sudha Ramachandran, *The Threat of Islamic Extremism to Bangladesh*, The Mail Archive, July 27, 2005, *at* http://www.mail-archive.com/cia-drugs@yahoogroups.com/msg00909.html (on file with the *Columbia Law Review*).

118. *See* Lisa Friedman, *Bangladesh Endures Ugly Experiments in "Nature's Laboratory,"* N.Y. Times Climate Wire, Mar. 9, 2009, *at* http://www.nytimes.com/cwire/2009/03/09/09climatewire-ugly-experiments-in-natures-laboratory-10035.html (on file with the *Columbia Law Review*).

119. *See* John Podesta & Peter Ogden, *The Security Implications of Climate Change*, Wash. Q., Winter 2008, at 118 ("The combination of deteriorating socioeconomic conditions, radical Islamic political groups, and dire environmental insecurity brought on by climate change could prove a volatile mix with severe regional and potentially global consequences.").

120. *See China Sees Climate Impacts Ahead*, BBC News, Apr. 23, 2007, *at* http://news.bbc.co.uk/2/hi/science/nature/6585775.stm (on file with the *Columbia Law Review*).

121. *Id.*

122. Podesta & Ogden, *supra* note 119, at 117-20.

123. *See* Boko et al., *supra* note 90, at 435.

124. The United States imports several hundred thousand barrels of oil a day from Nigeria, making Nigeria the fifth largest oil exporter to the United States. Energy Info. Admin., U.S. Dep't of Energy, Crude Oil and Total Petroleum Imports Top 15 Countries (2009), *at* http://www.eia.doe.gov/pub/oil_ gas/petroleum/data_publications/company_level_imports/current/import.html (on file with the *Columbia Law Review*).

125. *Id.*

126. *Id.*

a central government weakened by reduced agricultural production, flooding in Lagos, and already weak institutions. There is, of course, no way to predict exactly how these events might play out, let alone to quantify them. Yet, as is familiar from American history in the Middle East, the United States considers threats to its oil supply to be threats to its national security.

The United States has significant security interests in the Middle East as well. Among the threats to stability in this historically volatile region is the possibility of severe water shortages combined with rapidly growing populations.[127] The Middle East and adjacent North Africa have 6.3% of the world's population, but only 1.4% of its renewable freshwater.[128] With the exception of Turkey, every country in the region depends on water that originates outside its borders.[129] Climate change will likely adversely affect surface availability of major rivers in the region, like the Euphrates and the Tigris, which will increase in the winter and decrease in the spring.[130] The danger here is that competition for freshwater will exacerbate existing regional tensions and perhaps lead to violent conflicts. This is entirely plausible given the history of serious conflicts over precious water resources in the region.[131]

There is no satisfactory way to estimate the costs of these security concerns. Much depends on exactly which security issues arise and how the United States and others respond. We can, however, fairly conclude that climate change raises the stakes for the United States with respect to global security issues, and that this threat is likely to translate into economic costs as well. One could fairly respond to the scenarios described above by saying that they are highly speculative, virtually impossible to model, and extraordinarily challenging to quantify. Nevertheless, sensible policy cannot simply ignore the potential for climate change to trigger events that would be costly for the United States. To be sure, any projected costs must be discounted to reflect the uncertainties involved, but to simply ignore these risks is intellectually indefensible.

C. Migration

In many parts of the world, climate change will present challenges that make life not simply difficult, but impossible. When populations are unable to survive where they are, they will do what people have done in similar situations throughout human history: They will move.[132]

On a small scale, migration can help to reduce the stress in some regions while bringing a needed increase in population to another. This has been, for example, the story of migration from East to West within the United States. On a massive scale, however, migration's results are often much less benign.

To illustrate, consider the most likely source of spillover into the United States: migration from Latin America. Even now, the impact of unauthorized immigration on the United States is significant. Northern Mexico is expected to suffer severe water shortages as the earth warms, creating a large increase in U.S. immigration.[133] If the United States is unwilling to admit larger numbers of Mexican immigrants legally, we can expect them to cross the border without authorization, amplifying the pressures and challenges of unauthorized immigration.

If history is any guide, racial animosities may be exacerbated as locals resist the arrival of new populations and the (real or perceived) impact on employment, political influence, social services—and competition for resources.[134] Quite apart from one's views on unauthorized immigration, substantial additional migration caused by climate change would have economic implications in North America.

While it is impossible to quantify the costs associated with climate-induced migration, the impacts will be real, and the appropriate political response will require U.S. resources. The fact that the leading economic models overlook such costs leads to an incomplete picture of what the United States stands to lose from climate change impacts that occur elsewhere.

D. Disease

Economic costs estimates to date have excluded transmission of disease into the United States as a result of climate change. The global disease burden will likely increase as a result of climate change as disease both becomes more prevalent in the world and the resources to contain disease become less available.[135] Although scholars have anticipated

127. Farzaneh Roudi-Fahimi et al., Population Reference Bureau, Finding the Balance: Population and Water Scarcity in the Middle East and North Africa 2 (2002), *available at* http://www.prb.org/pdf/FindingTheBalance_Eng.pdf (on file with the *Columbia Law Review*).
128. *Id.* at 1.
129. Podesta & Ogden, *supra* note 119, at 122.
130. *See* Victor Cruz et al., *supra* note 89, at 483.
131. In 1990, Turkey disrupted the water supply from the Euphrates River into Syria to fill a Turkish reservoir. Turkey threatened to cut off the water supply when Syria supported the Kurdish Workers Party. Turkey also possesses the ability to cut off the water supply to northern Iraq. Podesta & Ogden, *supra* note 119, at 122. Water allocation also remains a contentious issue in Israeli-Palestinian negotiations and in Israeli-Syrian negotiations over the Golan Heights. Israel remains highly dependent on water from outside its borders. *Id.*
132. Michael McCarthy, *Climate Change "Will Cause Refugee Crisis,"* CommonDreams.org, Oct. 20, 2006, *at* http://www.commondreams.org/headlines06/1020-05.htm (on file with the *Columbia Law Review*) ("Mass movements of people across the world are likely to be one of the most dramatic effects of climate change in the coming century.").
133. *See Age of Consequences*, *supra* note 108, at 56 ("Northern Mexico will be subject to severe water shortages, which will drive immigration into the United States in spite of the increasingly treacherous border terrain."). Some of this migration has already begun to occur. Andrew Simms & Hannah Reid, Working Group on Climate Change and Dev., *Up in Smoke? Latin America and the Caribbean: The Threat From Climate Change to the Environment and Human Development* 40 (2006), *available at* http://assets.panda.org/downloads/upinsmoke_lac.pdf (on file with the *Columbia Law Review*).
134. *See* Rafael Reuveny, *Climate Change-Induced Migration and Violent Conflict*, 26 Pol . Geography 656, 659 (2007).
135. Anthony J. McMichael et al., Global Climate Change in Comparative Quantification of Health Risks 1543, 1609 (Majid Ezzati et al., World Health Org. eds., 2004), *available at* http://www.who.int/publications/cra/chapters/volume2/1543-1650.pdf (on file with the *Columbia Law Review*).

some of the adverse health impacts of climate change, current predictions are almost certainly low because of the inherent limitations of the models.[136] This threat, like those posed by national security concerns, is difficult to quantify but nonetheless real.

The volume of population displacement discussed above likely will augment the extent of these health impacts. It is unlikely that the ultimate destinations of most refugees will be adequately prepared.[137] Thus, public health infrastructures could be strained, likely in places where they are already quite fragile yet most needed. Even balanced with some positive health implications (such as decreased mortality from cold), the impacts of climate change on global health "will be overwhelmingly negative."[138] Additionally, climate change may have implications for the emergence of new diseases. Ecological changes factor directly in the emergence of new diseases,[139] and indirect factors like migration and public health infrastructure breakdowns will likely be exacerbated by climate change.[140]

The direct effects of disease on the United States are significant—climatic conditions in the United States are expected to become more hospitable to the root causes of pathogens like Lyme disease and West Nile virus[141]—but the indirect effects are much greater.[142]

Preventing the introduction and spread of infectious diseases is extraordinarily difficult and, depending on the nature of the disease, could prove impossible. Diseases arrive through a variety of pathways, including migration of people or animals,[143] travel,[144] and transportation of goods.[145] West Nile virus, malaria, avian flu, monkeypox, SARS, and Rift Valley fever have all traveled across national borders through one or more of these means. As the global disease burden grows, the incidence of such transmissions (including to the United States) can be expected to grow as well.[146] Given all of the possible pathways for transmission, no country can prevent the introduction of infectious agents without changes that seem politically and economically infeasible, such as substantial prohibitions on travel and radically reduced trade.[147]

The economic costs associated with an outbreak are not simply the obvious ones of public health measures, treatment, loss of life, and reduced productivity, but also the economic ripple effects of employee absenteeism and substantially reduced demand on the services sector as people avoid contact with others.[148] Infectious diseases can also

136. *Id.* (noting potential omissions include "many infectious diseases, the health consequences of drought and famine[,] ... population displacement, destruction of health infrastructure in natural disasters, . . . and risk of conflict over declining natural resources").

137. The increased health risks of mass displacements are already apparent from the incidence of disease and other health problems in existing refugee settlements. *See, e.g.*, Joseph Fair et al., *Lassa Virus-Infected Rodents in Refugee Camps in Guinea: A Looming Threat to Public Health in a Politically Unstable Region*, 7 Vector-Borne & Zoonotic Diseases 167 (2007).

138. Ulissess Confalonieri et al., Human Health, *in* IPCC, Impacts, *supra* note 20, at 391, 407.

139. S.S. Morse, Factors and Determinants of Disease Emergence, 23 Sci. & Technical Rev. 443, 445 (2004). We have seen this effect already. For example, the emergence of the Nipah virus in Malaysia was related to deforestation, drought, and increased pig farming. The virus caused encephalitis in humans with a 38% mortality rate and devastated the Malaysian pig industry. R.C. Bengis et al., *The Role of Wildlife in Emerging and Re-Emerging Zoonoses*, 23 Sci. & Technical Rev. 497, 499-500 (2004).

140. Morse, *supra* note 139, at 445 tbl. 1.

141. *See* Field et al., *supra* note 20, at 625 (discussing relationships between climate change, West Nile virus, and Lyme disease).

142. *See, e.g.*, Jonathan A. Patz et al., *The Potential Health Impacts of Climate Variability and Change for the United States: Executive Summary of the Report of the Health Sector of the U.S. National Assessment,* 108 Envtl. Health Persp. 367, 373 (2000) (suggesting past weather shifts may have caused worldwide epidemics, such as lepitosis in Nicaragua and Brazil, Lyme disease in United States and Europe, and dengue fever in Mexico).

143. The degree of the health impact related to migration is largely determined by two factors: (1) the degree of difference between health in the migrants' countries of origin and the United States; and (2) the size of the migratory population entering the United States. Brian D. Gushulak & Douglas W. MacPherson, *Globalization of Infectious Diseases: The Impact of Migration*, 38 Clinical Infectious Diseases 1742, 1742-43 (2004). Both of these factors will increase as a result of climate change. Much of the developing world will be severely affected by climate change, and as a result there will be more desperate attempts to migrate to the United States. In addition, warmer temperatures in the United States will create conditions more favorable to mosquito hosts and to the incubation of disease within the host, further enhancing the risk of local transmission.

144. Disease can be spread through human travel or accidental simultaneous transport of carriers like mosquitoes. We also see the implications of travel for the spread of disease with "airport malaria," locally acquired malaria clustered near international airports. Andrew J. Tatem et al., *Estimating the Malaria Risk of African Mosquito Movement by Air Travel*, Malaria J., July 2006, at 1, 3.

145. Most often disease from trade in goods involves trade in animals, though there are other means. Rift Valley Fever was transmitted from Africa to the Arabian Peninsula through livestock trade and ultimately infected 1,700 people. C. Brown, *Emerging Zoonoses and Pathogens of Public Health Significance—An Overview*, 23 Sci. & Technical Rev. 435, 437 (2004). Mad cow disease is also transmitted through trade, and fears of its spread have led to bans on imports and destruction of animals. *See* Thomas E. Walton, *The Impact of Diseases on the Importation of Animals and Animal Products*, 916 Annals of the N.Y. Acad. Science 36, 40 (2000). Finally, another established mode of transmission is through migratory animals, especially wild birds, who played a significant role in the transmission of avian flu. *See* Bjorn Olsen et al., *Global Patterns of Influenza A Virus in Wild Birds*, 312 Science 384, 384 (2006).

146. As the incidence of such diseases rise, the likelihood that refugees and immigrants will arrive carrying an infectious disease also will increase. Obviously, migrants harboring an infectious disease could infect local populations within the United States. John R. MacArthur et al., *Probable Locally Acquired Mosquito-Transmitted Malaria in Georgia,* 1999, 32 Clinical Infectious Diseases e124, e127 (2001). Certainly, communities can and do put measures in place to reduce such transmissions, but those measures have costs. And we should not assume that control measures are 100% effective. As the incidence of disease increases, the spread of infectious disease most likely will continue and sharpen despite the implementation of control measures.

147. The United States already recognizes the importance of other countries' preparedness, surveillance and detection, and containment to reduce or prevent the spread of disease. President Bush and Congress authorized $434 million in expenditures to facilitate these activities in other nations and reduce the risk of a pandemic flu outbreak. U.S. Dep't of State, United States International Engagement on Avian and Pandemic Influenza 2 (2007), *available at* http://www.state.gov/documents/organization/95933.pdf (on file with the *Columbia Law Review*).

148. *See* World Bank, East Asia Update November 2005: Countering Global Shocks 13 (2005), *available at* http://siteresources.worldbank.org/INTEAPHALFYEARLYUPDATE/Resources/EAP-Brief-final-full2.pdf

affect animals, including valuable livestock.[149] Taking these diverse costs into account, the total immediate economic effect of SARS in East Asia is estimated at 2% of the regional GDP at the time, although the number of deaths was limited to 800.[150] Projections for an influenza pandemic are much higher.[151]

SARS illustrates the difficulty and expense of controlling the spread of disease. In Taiwan, 151,270 people were quarantined and over 2.7 million passengers had their temperatures taken.[152] Taiwan is a country with eighteen airports, only two of which are international, and a population of approximately twenty-three million people. Imagine the astronomical social and economic costs of trying to replicate that response for a country the size of the United States.

Imagine further what would be required in Indonesia, a country of 222 million people and seventy-one airports (seventeen of which are international). There, or in the many other places where the impact is expected to be far worse than in the United States, it is reasonable to assume that public health infrastructure will be more strapped, that public officials will be more overwhelmed, and that governments with already-fragile economies will be more concerned about the economic consequences of reporting outbreaks. Thus, the United States can expect more delays and less openness from affected nations when it comes to reporting potential infections—the direct opposite of the integrated global alert and response system that the World Health Organization (WHO) says is necessary to prevent widespread outbreaks.[153] In the interconnected modern world, the United States not only is susceptible to imported diseases, but also heavily dependent on cooperation with other nations to prevent and limit outbreaks.

IV. The Rational Case for Action

The dilemma of climate change is often described (accurately) as a collective action or public goods problem.[154] No single country has an incentive to control its GHG emissions optimally because the cost of those emissions are borne by all countries, while the benefits are enjoyed entirely by the emitting state. The standard prediction of such problems is that each player, if behaving rationally, should "free ride" on the efforts of the others.

One might think, therefore, that it is in the self-interest of the United States to do nothing, or very little. A slight variation is that the United States should not act unless all other major contributors to climate change also take action. A common argument in contemporary political discourse is that American business, especially energy-intensive trade-exposed manufacturers, will be put at a competitive disadvantage if countries like China do not adopt comparable mitigation measures.[155] Thus far, high emitting developing countries—notably India and China—have signaled their reluctance to make binding commitments.[156] The result is a dangerous stalemate.[157]

We certainly agree that the problem of climate change is global and requires a collective solution by the major emitters and largest emerging economies. Even aggressive domestic mitigation efforts by the United States could not, without more, stabilize and mitigate its effects. Yet that reality does not answer the question whether it is in the interest of the United States to address climate change—to cut emissions at home and subsidize reductions elsewhere—even in the face of reluctance by some other major emitters to act.

In the face of a collective action problem, large players may internalize enough benefits to justify an investment in the production of those goods. Every player, large or small, has an incentive to take action up to the point where the marginal cost of further action equals the marginal benefit. A large hegemonic player like the United States internalizes a significant fraction of the global gains, making it worthwhile to bear at least some costs.

To illustrate, consider the (admittedly controversial) estimates provided by the Stern Review, placing the annual cost of stabilizing GHGs at approximately 1% of global GDP by 2050.[158] World GDP in 2007 was approximately $54 trillion, $13.8 trillion of which was accounted for by the United States.[159] The estimated cost of a global stabilization of GHGs, then, would represent less than 4% of American GDP. Even if the Stern Report understates stabilization costs dramatically, the costs to the United States of failing to act are likely to remain larger than the total

(on file with the *Columbia Law Review*) ("[D]uring SARS ... people tried to avoid infection by minimizing face-to-face interactions, resulting in a severe demand shock for services sector....").

149. *See id.* at 12.

150. *Id.* at 13.

151. *See id.* at 14 ("[A] new flu pandemic could lead to between 100,000 and 200,000 deaths in the US, together with 700,000 or more hospitalizations, up to 40 million outpatient visits and 50 million additional illnesses.").

152. Kow-Tong Chen et al., *SARS in Taiwan: An Overview and Lessons Learned*, 9 Int'l J. Infectious Diseases 77, 82 (2005).

153. World Health Org., Global Outbreak and Response Network—GOARN, *available at* http://www.who.int/csr/outbreaknetwork/goarnenglish.pdf (last visited Sept. 11, 2009) (on file with the *Columbia Law Review*).

154. *See* Kenneth J. Arrow, *Global Climate Change: A Challenge to Policy*, Economists' Voice, July 2007, at 3, *available at* http://www.bepress.com/ev/vol4/iss3/art2 (on file with the *Columbia Law Review*). Daniel Cole, *Climate Change and Collective Action*, 61 Current Legal Probs. 229 (2009), *available at* http://ssrn.com/abstract=1069906 (manuscript at 4, on file with the *Columbia Law Review*).

155. *See, e.g,* Sen. Pete V. Domenici & Sen. Jeff Bingaman, U.S. Senate Comm. on Energy and Natural Res., *Design Elements of a Mandatory Market-Based Greenhouse Gas Regulatory System* 14 (2006) ("[W]ithout greenhouse gas mitigation efforts by all major emitters, including our largest trading partners, the U.S. economy could be placed at a competitive disadvantage.").

156. Jonathan Weisman, *G-8 Climate-Change Agreement Falls Short*, Wall St. J., July 9, 2009, at A8 (describing how at G-8 conference "[d]eveloping countries have responded that they shouldn't have to slow or sacrifice their fossil-fuel-based economic growth to help the West atone for its historical consumption patterns").

157. Again, since this Article was originally published, the major economies of the world have signed the Copenhagen Accord, described *supra* note 15. The Accord is not an international treaty containing binding mitigation targets.

158. There is a range of +/- 3% around this estimate, meaning that the costs are likely to fall somewhere between 4% and -2% of GDP. Stern Review, *supra* note 5, at 279.

159. World Bank Indicators, *supra* note 92.

global costs of acting. If, for example, one doubles the Stern estimate, the total global cost of stabilizing GHGs is 8% of U.S. GDP. As shown in Table 3 below, the cost of climate change to the United States is likely to exceed 10% of GDP.

Consider now that, taken together, the United States and the EU account for 58% of global GDP.[160] If they were, jointly, to bear the global cost of stabilization the impact would be less than 2% of their combined GDP. Broadening the pool of countries further, the cost of stabilization would be approximately 1.3% of the GDP for OECD countries.[161]

Assuming GHGs could be stabilized at 500-550ppm by 2050, and the total global cost of doing so would be approximately 4% of U.S. GDP, we have figures against which to compare the costs of climate change. The following table provides a partial summary of how the conventional assessment of economic harm to the United States might be adjusted, accounting for the factors we have discussed that cause that conventional estimate to understate harms.

Table 3: Quantitative Adjustments to Conventional Estimates of Climate Change Impacts

Factors Considered	Conventional Estimates of Reduction in U.S. GDP (%)	Marginal Impact on Annual GDP (%)
Conventional IAM Estimate	0.5	0.5
Optimism About Temperature Rise	0	1
Asymmetry Around Point Estimates	0	0.5
Catastrophic Events	0	0.5-3
Nonmarket Costs	0	1.4-3.5[162]
Export Losses	0	1.5
SUBTOTAL	**0.5**	**5.4-10**
Growth and Productivity	0	Double Above Impacts
TOTAL	**0.5**	**10.8-20**

Several factors discussed in this Article are omitted from the above table because we are unable to estimate their impact in quantitative terms. It is important not to lose sight of these potential harms, which are presented in Table 4.

Table 4: Qualitative Adjustments to Conventional Estimates of Climate Change Impacts

Factors Considered	Examples of Impacts
Cross-Sectoral Effects	If climate change affects energy prices, agriculture will be affected
Supply Shocks from Abroad	Energy prices
Global Financial Markets	Impact on American investments abroad; lending to fund current account deficit
National Security	Political Destabilization; resource conflicts; need for militaryresponse (e.g., total cost of Iraq War to 2009 = $3 trillion[163])
Migration	Racial and ethnic tensions, undocumented immigration,
Disease	Pandemics; new diseases

The impacts presented in Table 4 are not minor. National security, for example, could easily generate costs that exceed any of those listed in Table 3. The estimate produced in Table 3, therefore, most likely understates the full impact of climate change.

To be sure, the figures presented above are highly speculative. Yet the impacts we have identified and sought to quantify represent a critical set of issues for policy debates about climate change. We are confident that estimating each of these effects to be zero (as is often done) is much less accurate.

With these limitations in mind, what is the lesson for U.S. policy? If we simply tally the effects presented above in Table 3, the resulting impact of climate change on GDP reaches 7.7%,[164] excluding the impact on growth and productivity. If we follow Fankhauser and Tol,[165] estimating that capital accumulation effects on productivity would double this figure, the total decrease in GDP is 15.4%. To this, one would have to add the factors from Table 4.

If one accepts the estimate of a 15.4% impact on the United States (or even 7.7%), and if one accepts that the global cost of action would be about 4% of U.S. GDP, the obvious conclusion is that the United States would be better off paying the full cost of mitigating the impact of climate change by itself rather than allowing the world to continue in a "business as usual" fashion. This result is even stronger if Europe and perhaps the rest of the OECD are assumed to participate.

The point here is not that the United States should actually bear these costs alone (or even that it could do so if it wanted to). Rather, the point is that it may still make sense

160. *Id.*

161. World Bank, Key Development Data & Statistics, *at* http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html (last visited Sept. 18, 2009) (on file with the *Columbia Law Review*). We can expect the American and European share of global GDP to shrink because the economies of other states like China and India continue to grow rapidly. That said, the United States and the OECD represent a substantial share of global GDP for the next hundred years under any plausible assumptions about growth rates. As such, the United States will have an interest in bearing a large share of the global costs of reductions in emissions.

162. This includes only biological costs.

163. Joseph E. Stiglitz & Linda J. Bilmes, The Three Trillion Dollar War: The True Cost of the Iraq Conflict (2008).

164. Where there is a range of costs in Table 3, we have used the midpoint to calculate the total impact.

165. Fankhauser & Tol, *supra* note 82, at12-14.

for the United States to invest in mitigation without waiting for every other major country to act. While the problem is indeed a collective action problem, free riding is not a rational strategy for a player as large as the United States.

At a minimum, all of this suggests that the United States should put considerable energy into the negotiation and entry into force of an effective international treaty to address climate change concerns. Beyond that, it suggests that if such a treaty is not possible in the near term, the United States may wish to enact significant domestic measures to reduce domestic emissions of GHGs.

This argument is subject to an important caveat about the impact of the discount rate on the analysis. There is a dramatic difference between expenditures today and costs borne many years in the future. To evaluate costs and benefits across time it is necessary to specify some discount rate, and the choice of discount rate is the source of much debate within climate change discussions. Our own view is that a low discount rate is more appropriate, and our reasons reflect those that have already been discussed in the literature.[166] We simply flag the issue here, noting that if one chooses a sufficiently high discount rate, even the costs and benefits mentioned above will not support an argument for substantial expenditures today.

There remain some potentially credible arguments against unilateral action by the United States, including the futility, leakage, and fairness arguments we mentioned in the introduction. Although we do not tackle them in detail here, the persuasiveness of these arguments is not self-evident. The first two require an empirical defense: how much mitigation is so little that it is not worth acting? Will unilateral action in fact lead to massive flight of energy intensive industry? The third argument requires a normative defense. We note only that there are certainly competing views on this question.

Although it is conceivable that a credible U.S. threat to do nothing until the major emerging economies agree to share the burden of mitigation could increase the prospects of persuading other countries to participate in a new global climate change regime, the climate change winner argument is fatally flawed regardless. This Article will have succeeded if the strategic question of how best to induce cooperation becomes the focus of the climate change debate, and the climate change winner argument is abandoned.

V. Conclusion

Our goal in this Article has been to debunk the climate change winner argument, which suggests that because the United States will fare better than many nations of the world as global temperature increases, it is not in the interest of the United States to take aggressive action to mitigate greenhouse gas emissions.

Our argument shows that the leading economic models of climate change's impacts are methodologically limited in ways that systematically skew toward an understatement of costs. The models understate some impacts because of their optimistic assumptions about the rate and magnitude of warming and fail to account for certain categories of impacts that are difficult to quantify. In addition, leading models tend to adopt a myopic single economy view that does not account for international spillover effects. We think this kind of mistake is the linchpin of the climate change winner argument: the argument only succeeds if we assume that climate change impacts in other parts of the world do not reverberate in the United States.

Economists may well appreciate these shortcomings, but policymakers may not. It would be irresponsible to base policy recommendations on current models without acknowledging their significant limitations. A more developed accounting of the costs associated with climate change not only calls the climate change winner argument into question but shows it to be wrong.

166. The most central reason for a low discount rate relies on the notion that the welfare of future generations should be valued on par with our own. *See* William Nordhaus, A Question of Balance: Weighing the Options on Global Warming Policies 169-90 (2008); Stern Review, *supra* note 5, at 35. *But see* Robert O. Mendelsohn, *A Critique of the Stern Report*, Reg., Winter 2006-2007, at 42-43 ("[U]sing low discount rates is unfair to every generation; the welfare of future generations will be reduced by low discount rates just as much as current ones.").